

May 22, 1934.

F. HODGKINSON

1,959,786

HYDRAULIC ELEVATOR APPARATUS

Filed April 18, 1933

8 Sheets-Sheet 1

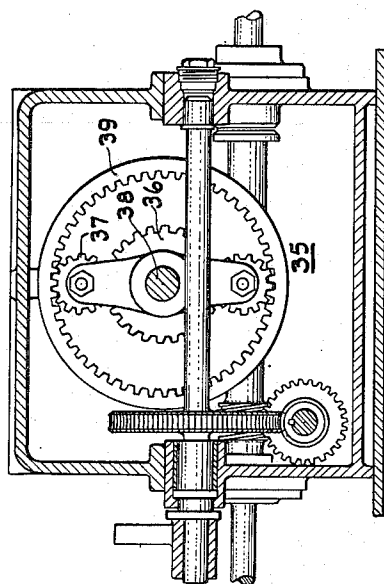
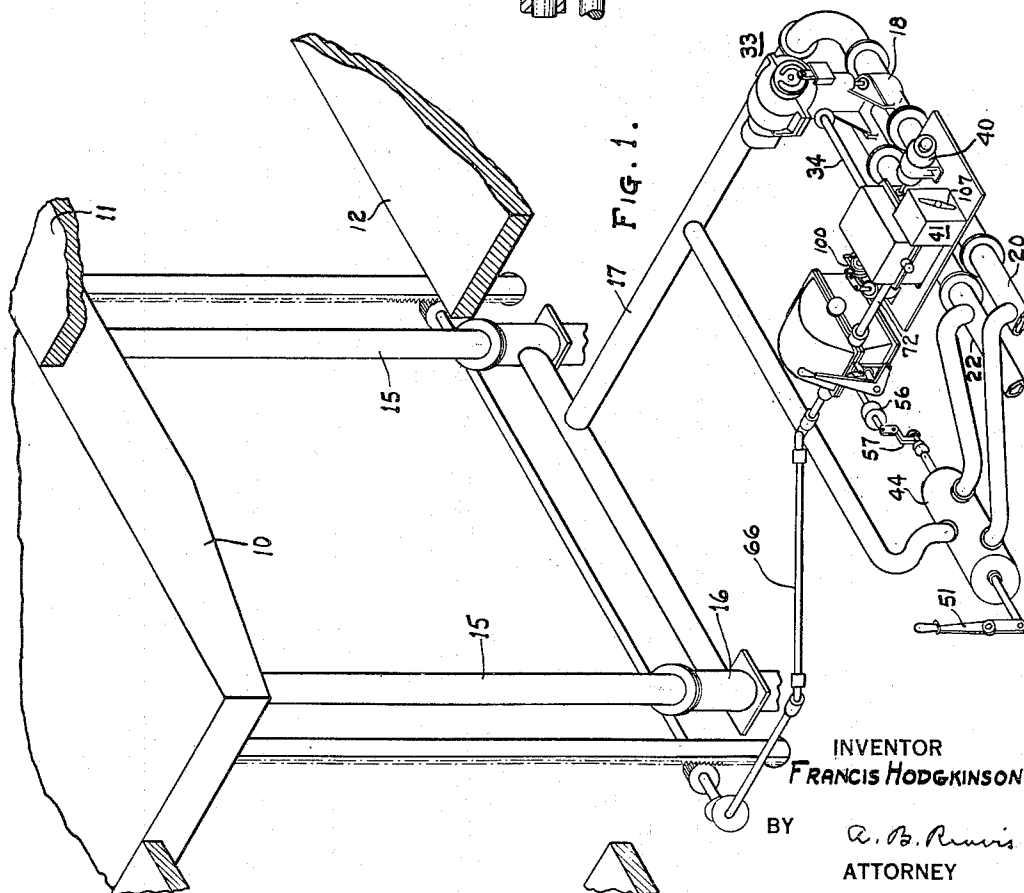


Fig. 6.



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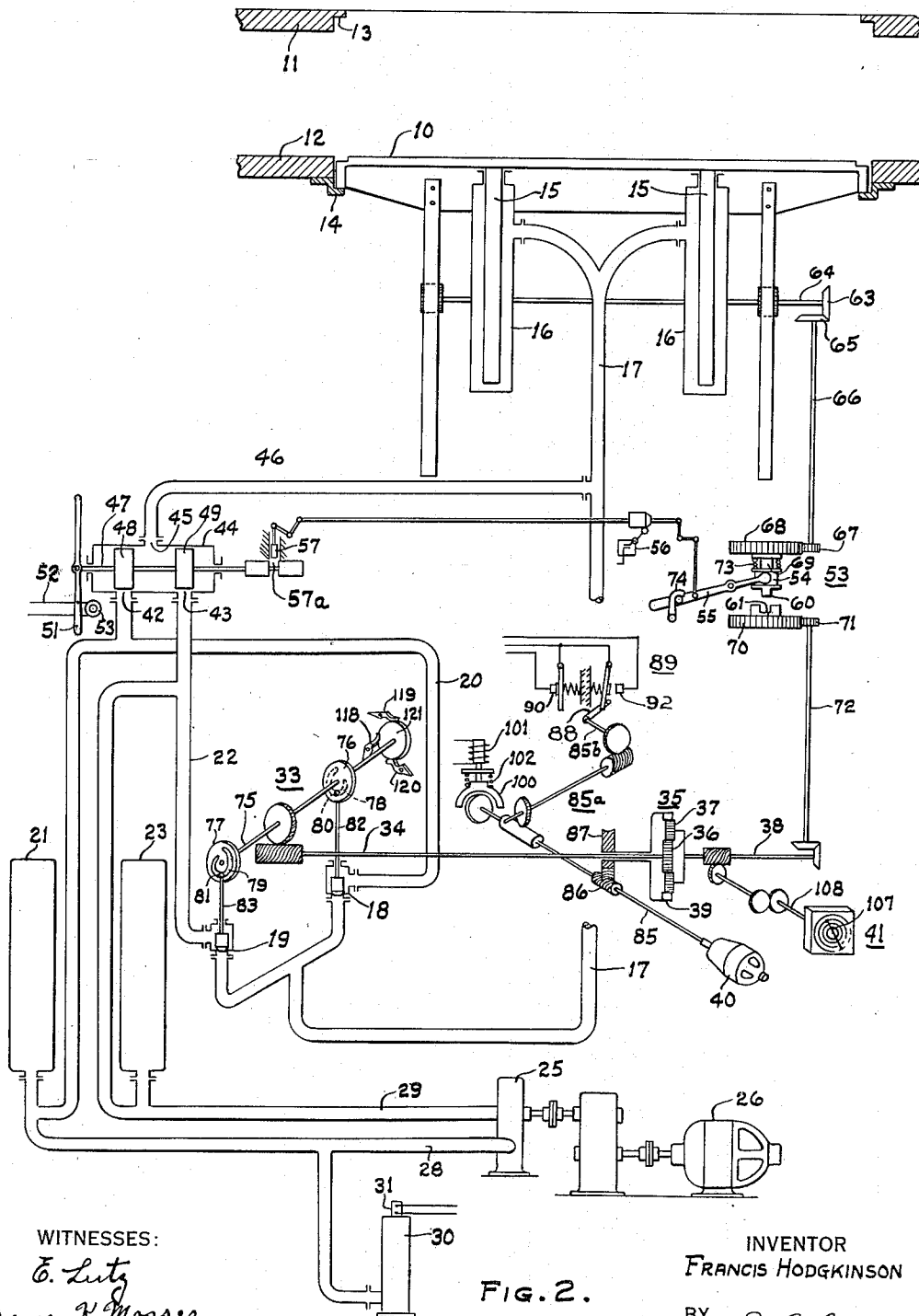
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Filed April 18, 1933

8 Sheets-Sheet 2



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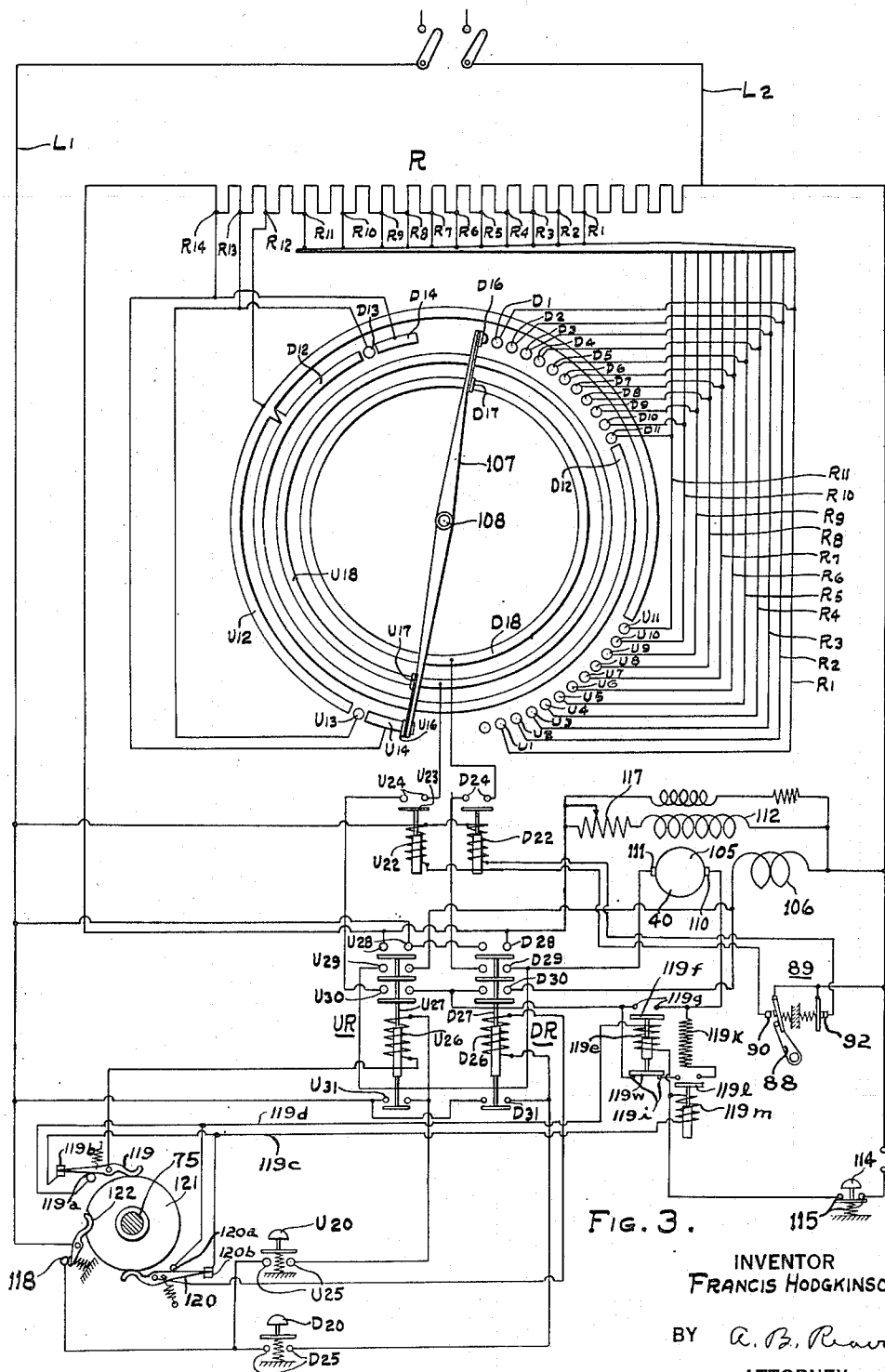
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FIG. 4.

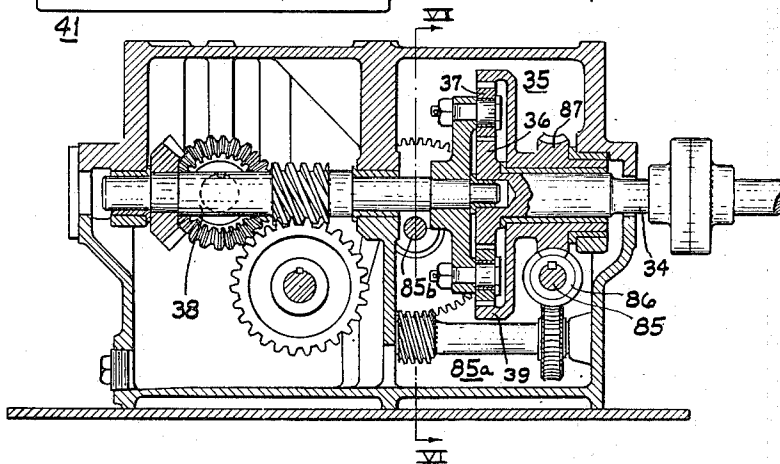
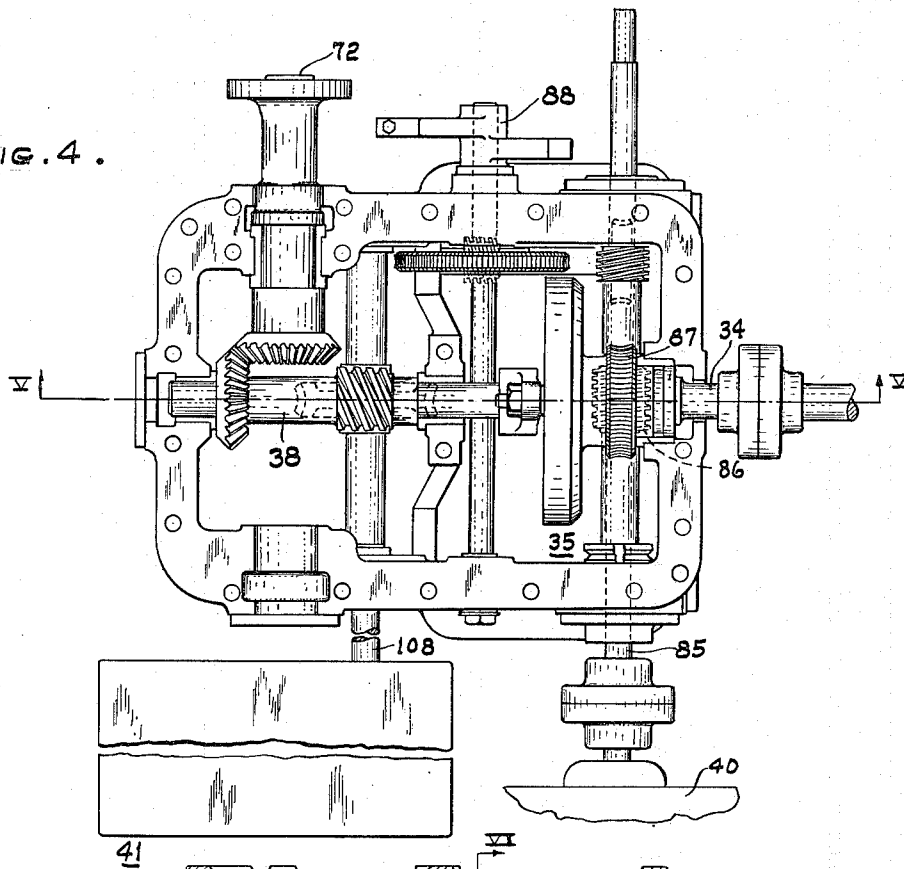


FIG. 5.

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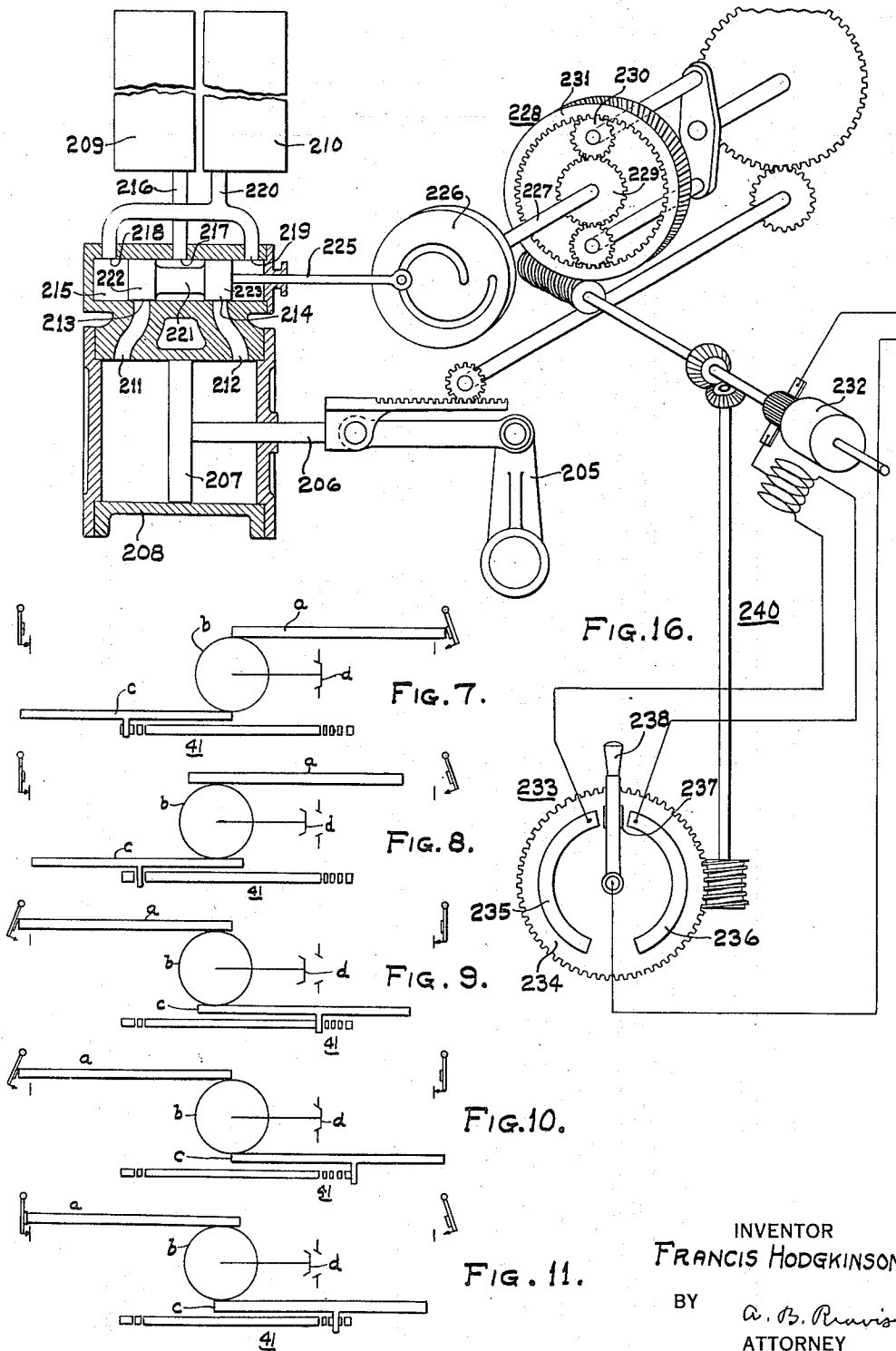
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HYDRAULIC ELEVATOR APPARATUS

Filed April 18, 1933

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May 22, 1934.

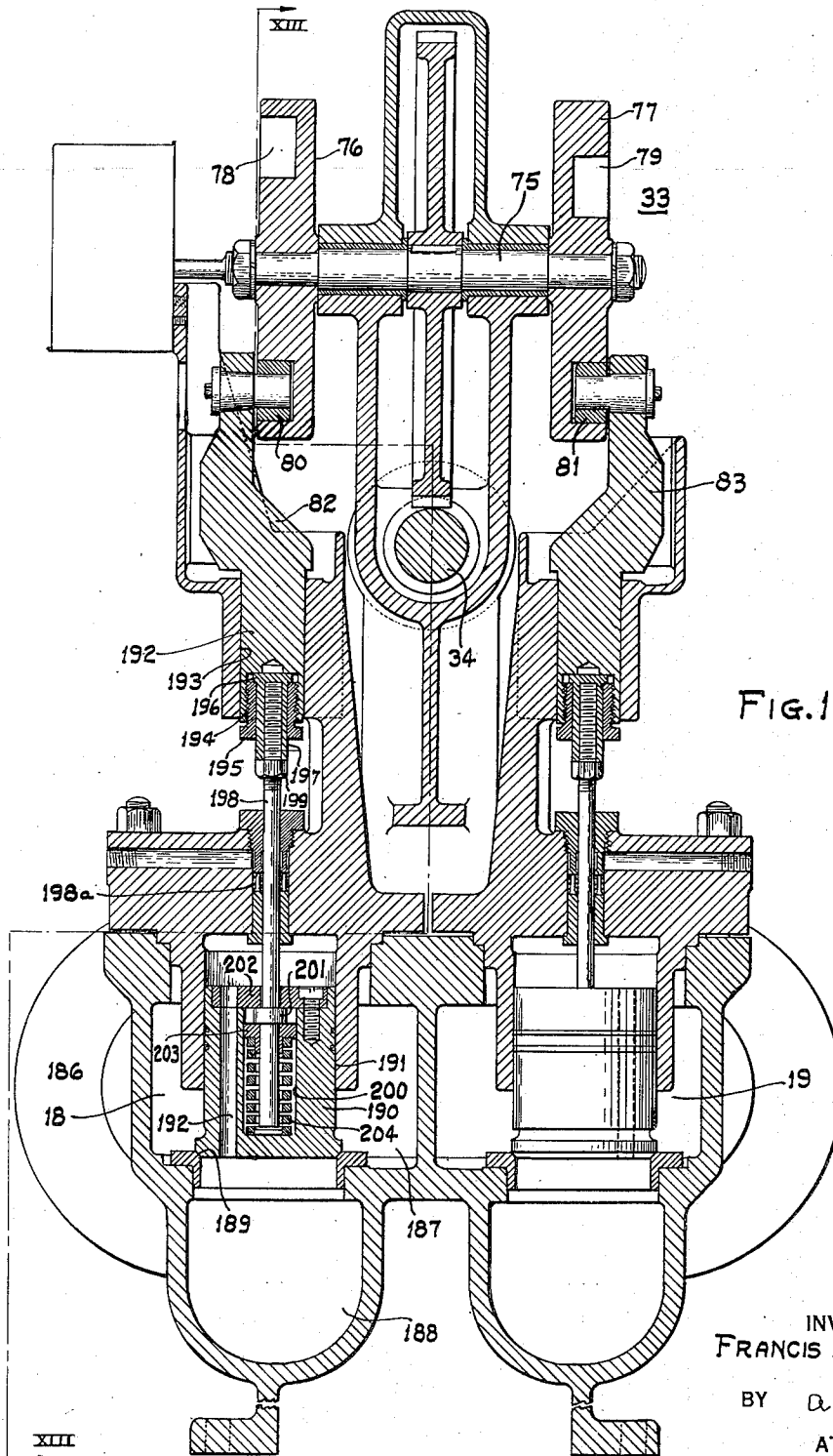
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8 Sheets-Sheet 6



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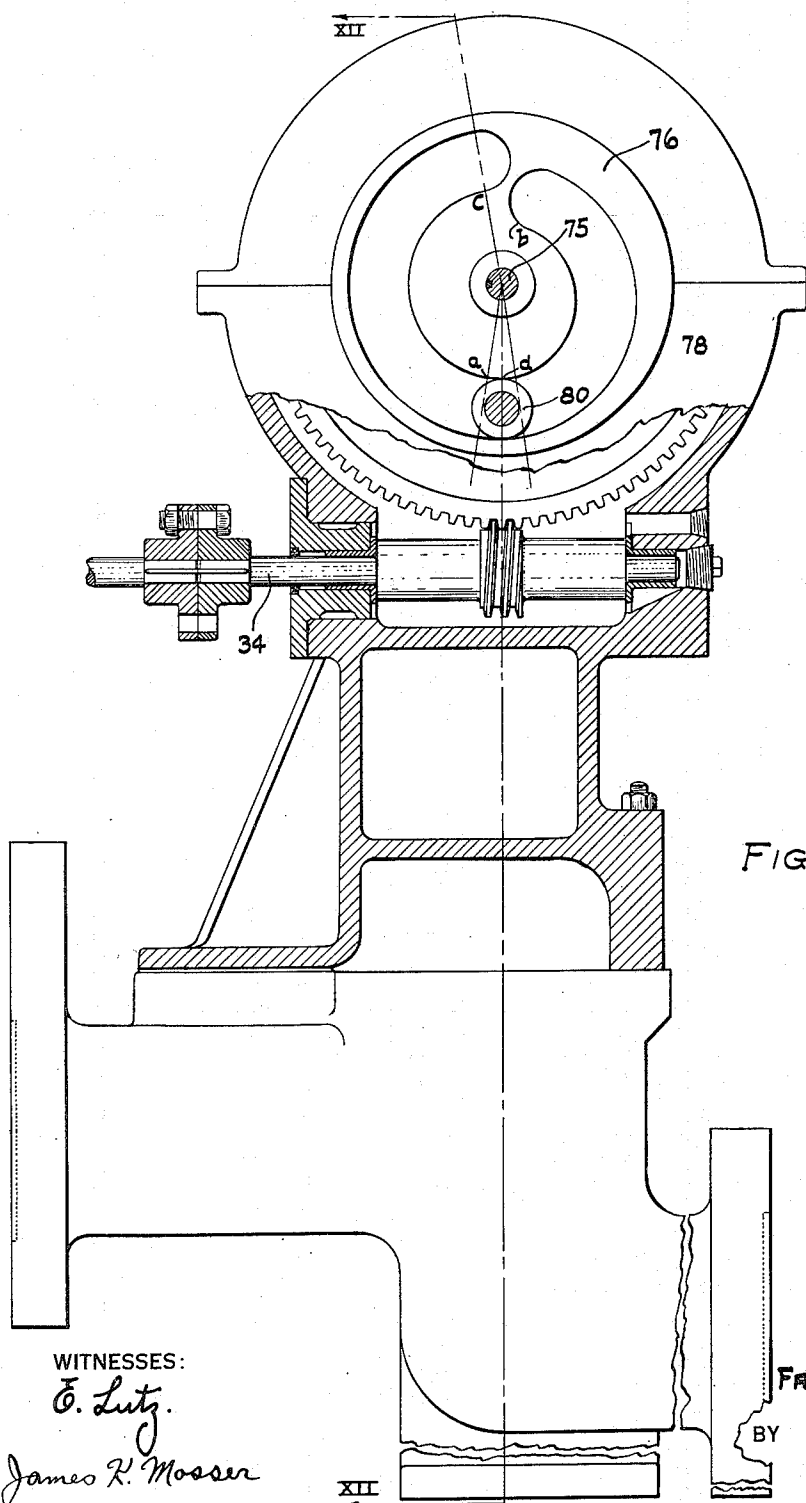
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HYDRAULIC ELEVATOR APPARATUS

Filed April 18, 1933

8 Sheets-Sheet 7



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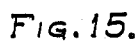
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8 Sheets-Sheet 8



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UNITED STATES PATENT OFFICE

1,959,786

HYDRAULIC ELEVATOR APPARATUS

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Application April 18, 1933, Serial No. 666,771

22 Claims. (Cl. 187—28)

My invention relates to control mechanism for hydraulic apparatus utilized for moving a body to and fro and it has for an object to provide improved means of this character wherein the application of energy medium to effect motion of the body is determined by the differential effect of controlling motion and motion of the body.

More particularly, my invention is concerned with control mechanism which is particularly useful in controlling a hydraulic elevator of the one-flight type, for example, an elevator such as is used to transport airplanes to and fro between an upper flying deck and a lower deck of an airplane carrier. An elevator of this character should make a trip quickly, should be properly accelerated at the start, and should be retarded as the end of the trip is approached. Acceleration, speed control and retardation should take place automatically upon starting and stopping, respectively. Accordingly, I have devised a control mechanism for accomplishing these results. I provide an opening and closing mechanism for the hydraulic admission and exhaust valves which is operated in response to the differential effect of a reversible pilot motor and of motion of the elevator, the pilot motor having a definite or predetermined travel. Assuming that the elevator is at one terminus and it is desired to cause the elevator to move to the other terminus, the pilot motor is started in the proper direction and motion of the pilot motor acts through the differential to open one of the valves, whereupon the elevator starts and is accelerated, motion of the elevator also being applied to the differential, whereby the latter controls the valves so that the elevator tends to follow the pilot motor—if the elevator tends to run ahead of the pilot motor, the differential responds and adjusts the active valve to slow down the elevator, and, if the elevator tends to lag behind the pilot motor, then the latter acts on the differential to adjust the active valve to speed up the elevator.

To retard the elevator incident to bringing it to a stop at a terminus, it is necessary that an active valve controlling the supply of motive fluid to the elevator cylinder or the exhaust of fluid from the latter shall be moved in a closing direction; and, to bring about this valve operation, it is necessary that the pilot motor shall be retarded or stopped before the end of a trip so that the motion of the elevator, operating through the differential may be effective to move the active valve in a closing direction to retard the elevator. The pilot motor is arranged for pre-

determined travel in either direction, the motor being brought to a stop by a limit switch and a brake responsive to motor travel. The pilot motor travel is selected or adjusted so that, with an active valve wide open, the motor will be brought to a stop with the elevator at such distance from a terminus that the motion of the elevator would be sufficient to close the active valve if the elevator were permitted to travel a short distance beyond the terminus, the elevator bringing about its own retardation and being stopped at a terminus by elevator shaft abutments and the elevator over-travel, which would be necessary to completely close an active valve, assuring that the active valve shall be not quite closed at a terminus to provide pressure to hold the elevator at the terminus. If loads were such that normal flight travels were each secured with an active valve wide open, stoppage of the pilot motor by its limit switch and brake would be sufficient to secure proper operation; however, variation in load results in variation in the extent of active valve opening. To the extent that the active valve opening is reduced, to that extent is the lag of the elevator with respect to the pilot motor reduced; and, on this account, stoppage of the pilot motor would occur with the elevator an insufficient distance from a terminus for it to bring about its own proper retardation. Therefore, in addition to the limit switch and brake, which are effective after predetermined motor travel, I also provide a potentiometer, which is effective, after predetermined elevator travel, to retard the pilot motor if the latter has not been already stopped by the limit switch and brake. Hence, irrespective of load variations and consequent variations in the extent of valve opening for flight travel, it is assured that the pilot motor shall be retarded or stopped with the elevator a sufficient distance from the terminus being approached so that the elevator may bring about its own retardation in such a manner that it is stopped at a terminus without undue shock; with an active valve wide open, the limit switch and brake effect this purpose; and, with fractional opening of an active valve, the potentiometer is effective to initiate retardation, the motor being retarded more and more until the limit switch and brake are operated, the smaller the fractional opening the more the motor is retarded by the potentiometer before the limit switch and the brake become effective to stop the motor.

A further object of my invention is to provide a hydraulic elevator having admission and ex-

haust valves which are opened and closed by a differential, the differential having motion applied thereto by a reversible pilot motor and by the elevator, whereby starting and stopping of the elevator as well as proper selection and operation of the valves is controlled or determined by operation of the pilot motor.

A further object of my invention is to provide a hydraulic elevator having its valves controlled by the differential effect of elevator motion and of a pilot motor with means to positively assure of retardation of the elevator beginning a predetermined or fixed distance before the end of a trip is reached.

A further object of my invention is to provide, in addition to the control mechanism aforesaid, a manual control arrangement for admitting and exhausting motive fluid to and from the elevator cylinders, an interlock being arranged between the manual control arrangement and the pilot motor and differential mechanism, whereby, when the manual arrangement is rendered effective a circuit breaker is caused to interrupt the pilot motor circuit and the connection between the elevator and the differential is interrupted, the connection between the elevator and the differential being of such a character that there is only one position of connection, that is, the elevator and the control mechanism must be in predetermined relative positions before the mechanical drive between the elevator and the differential may be restored, to assure that, if the elevator has been controlled manually, the automatic control may be restored with all parts in proper relative position.

These and other objects are effected by my invention as will be apparent from the following description and claims taken in connection with the accompanying drawings forming a part of this application, in which:

Fig. 1 is an isometric view showing an elevator with my improved control mechanism applied thereto;

Fig. 2 is a schematic view showing the elevator and its control mechanism;

Fig. 3 is a diagrammatic view showing the potentiometer and circuits for controlling the pilot motor;

Figs. 4, 5, and 6 are detail views of the control mechanism, differential gearing and associated parts, Fig. 5 being a section taken along the line V—V of Fig. 4 and Fig. 6 being a section along line VI—VI of Fig. 5;

Figs. 7 to 11, inclusive, are diagrammatic views illustrating effect of differential elevator and pilot motor motion in controlling the elevator;

Fig. 12 is a detail sectional view of the valves taken along the line XII—XII of Fig. 13;

Fig. 13 is a detail view showing one of the cams for operating the valves and taken along the line XIII—XIII of Fig. 12;

Fig. 14 is a cam diagram;

Fig. 15 shows a second embodiment of my invention; and,

Fig. 16 shows a third embodiment.

Referring now to the drawings more in detail, I show an elevator 10 movable between an upper flying deck 11 and a lower deck 12, the elevator being preferably stopped in alignment with the respective decks by stops shown at 13 and 14.

The elevator is raised and lowered by plungers 15 extending into hydraulic cylinders 16 connected by a conduit 17 with pressure and exhaust valves 18 and 19. The pressure valve 18 is con-

nected by a conduit 20 to a pressure tank 21, and the exhaust valve 19 is connected by a conduit 22 to the lower pressure or exhaust tank 23.

A pressure sufficiently above atmospheric to raise the loaded elevator, is maintained in the tank 21 by a pump 25 driven by a suitable motor 26. The outlet of the pump is connected by a conduit 28 to the high pressure tank 21 and the pump inlet is connected by a conduit 29 to the low-pressure or exhaust tank 23 wherein there is maintained a pressure low enough for the weight of the unloaded elevator platform to descend.

Regulation or control of the pressure in the tank 21 is secured by a pressure-regulator 30 connected to the conduit 28 and controlling a switch or controller 31 for the motor 26, a decline in pressure resulting in energization of the motor and pumping until the pressure is restored to a predetermined point, whereupon the switch or circuit breaker 31 for the motor is opened.

The pressure valve 18 and the exhaust valve 19 are opened and closed by automatic control mechanism including a cam mechanism, at 33, operated by the output shaft 34 connected to the output gear element of the differential, at 35, for example, to the sun gear 36, one input element of the differential, for example, the planet pinions 37, being connected to the elevator-driven shaft 38, and the other input element of the differential, for example, the orbit gear 39 being connected to the pilot motor 40. The automatic control mechanism also includes means for retarding and stopping the pilot motor after the latter has travelled a predetermined distance in either direction. In order that the elevator, acting through the differential, may bring about movement of an open valve, the pressure valve 18 or the exhaust valve 19, in a closing direction to effect retardation of the elevator, the elevator retardation should begin an adequate distance before a terminus is reached so that the elevator may be gradually retarded and stopped without material shock. As the pilot motor and the elevator are geared together through the differential and as it is necessary to start the pilot motor in order that motion of the latter relative to the elevator may cause the differential to open the valve corresponding to the desired direction of elevator travel, it will be apparent that the pilot motor leads the elevator, or rather the elevator lags with respect to the motor, the extent of lag depending upon how wide it is necessary to open the valve to carry the load. With a valve wide open, the elevator lag is a maximum, and the limit switch and brake, operative after predetermined travel of the pilot motor, are adequate for proper elevator retardation; however, with a fractional valve opening, and, therefore, less lag of the elevator, but for potentiometer, at 41, the elevator would be too near a terminus at the instant of operation of the limit switch and the brake to secure proper retardation, this difficulty being more and more pronounced as the valve opening becomes smaller and smaller. The smaller the valve opening, the less the time required to bring about closure, the elevator itself being at full speed at the initiation of closing, and the reduction of time of retardation may introduce dangerous or undesirable shocks. Therefore, the automatic control mechanism includes means, the limit switch and the brake, effective after predetermined travel of the pilot motor to stop the latter and means, the potenti-

ometer, at 41, effective after predetermined elevator travel, to bring about retardation of the pilot motor, the potentiometer being ineffective for the wide open valve and maximum elevator lag condition, when the limit switch and the brake stop the pilot motor with the elevator far enough away from a terminus for proper elevator retardation to take place, and the potentiometer being more and more effective to retard the pilot motor the smaller the fractional valve opening.

In addition to the automatic control mechanism for controlling the admission and exhaust of motive fluid to the elevator cylinders 16, I provide hand control means for this purpose, such means being interlocked with the automatic control such that the elevator is disconnected from the automatic control mechanism and a circuit breaker in the pilot motor circuit is opened whenever the manual control means is effective. To this end, I show the pressure and exhaust conduits 20 and 22 connected, for example, to spaced ports 42 and 43 of the valve housing 44, the valve housing having a port 45 disposed immediately of the ports 42 and 43 and connected by a conduit 46 to the conduit 17. A piston valve 47 is arranged in the housing 44 and has piston portions 48 and 49 arranged to cover and uncover the ports 42 and 43 so as to interrupt and afford communication of either the pressure conduit 20 or the exhaust conduit 22 with the conduit 46. The piston valve 47 may be operated by any suitable means, for example, by the hand lever 51. If desired, the lever 51 may be operated from a remote point, for example, by a cable 52 shown passing over the sheave 53 and connected to the lever 51.

When the elevator is to be subjected to manual control, the automatic mechanism must be disconnected. Accordingly, the transmission, at 53, between the elevator and the elevator-driven shaft 38 is provided with a one-tooth clutch including a movable element 54, which is moved by a lever 55. Operation of the lever 55, to disengage the clutch, brings about opening of the circuit breaker 56 of the pilot motor 40 and then disconnection of the latch 57 for the piston valve 47, permitting the latter to be moved. As will be apparent, particularly in view of more detailed description hereinafter contained, this arrangement provides an interlocking relation between the manual and automatic control devices, it being necessary to disconnect the automatic control before the manual control can be operated and it being necessary to bring the manual control to neutral before the automatic control can be restored.

A clutch having one tooth 60 engageable in a recess 61 is employed to assure that the elevator and the automatic control mechanism shall be in predetermined relative positional relation before the clutch can be reconnected. In order that a one-tooth clutch may be used effectively in this way, it is necessary that the clutch shall move less than a complete revolution for each elevator trip. Accordingly, therefore, I show the transmission, at 53, comprised by a gear 63 connected to the equalizer rack shaft 64 of the elevator and meshing with a gear 65 carried by the shaft 66, the shaft 66 having a pinion 67 meshing with the gear 68, the gear ratio being such that the gear 68 makes less than a complete revolution for each elevator trip. The gear 68 is connected to the shaft 69 to which is splined the movable clutch member or collar 54 having the single tooth 60 engageable in the recess 61 provided at one side of

the gear 70, the latter gear meshing with a pinion 71 carried by the shaft 72 geared to the elevator-driven shaft 38 of the automatic control mechanism, the gears 68 and 70 and the pinions 67 and 71 preferably being, respectively, of the same size so that the shafts 66 and 72 move at the same speed.

The movable clutch collar 54 and the lever 55 are biased in a clutching direction by the spring 73, a latch 74 being provided to hold the clutch disconnected. From Fig. 2, it will be seen that the latch or bolt 57 can enter the recess 57a only when the manually operated piston valve is in neutral position. Assuming that the piston valve 47 is in neutral and that the latch 74 is released incident to changing over from manual to automatic control, all interlocking motion, including engagement of the bolt 57 in the recess 57a and closing of the circuit breaker 56 will be accomplished as soon as the plane of the outer end of the single projection 60 reaches the plane of the top of the single recess 61; and, if the projection registers with the recess, the clutch would immediately engage. It may be that the projection and recess will not register, for example, the elevator may have been in "down" position when the change over from automatic to manual control was made, and the elevator is in "up" position when it is attempted to change back to automatic control; and, in this as well as any case where the projection does not register with the recess, one or the other of the "up" and "down" push buttons is operated, thereby securing movement of the automatic control mechanism and the clutch member having the recess 61; and, as soon as the recess registers with the projection, the latter snaps in under influence of the spring 73. While I have described bringing the manual valve 47 back to neutral before releasing the lever latch 74, it will be obvious that the contrary operation may be effected, the latch 74 being released but the spring 73 being ineffective to establish the interlocking relation until the valve 47 is moved to register the recess 57a with the latch 57.

Having described the apparatus somewhat in general, various features, particularly the automatic control mechanism for the pressure valve 18 and the exhaust valve 19 will now be taken up in greater detail.

The cam mechanism, at 33, includes a cam shaft 75 having cams 76 and 77 thereon, the cams being provided with similar spiral cam grooves 78 and 79 engaged by followers 80 and 81 provided at the upper ends of the stems 82 and 83 of the pressure and exhaust valves 18 and 19, respectively.

The cams 77 and 78 are arranged in relatively reversed relation and have such relative angular position that, in one position of the shaft 75, both the valve 18 and valve 19 are closed by the cams, if the shaft 75 is rotated in one direction, the pressure valve will be opened and the exhaust valve 19 will be maintained closed, and if the shaft 75 is operated in the other direction, the exhaust valve 19 will be opened and the pressure valve 18 will be maintained closed. Therefore, the cam mechanism, at 33, provides for the opening or closing of either valve or for closing both valves, these operations being effected by rotation of the shaft 34 either in one direction or the other dependent upon motion given to the differential, at 35, by the pilot motor 40 and by the elevator.

The reversible pilot motor 40 has a shaft 85 connected by the worm 86 and worm wheel 87 to an element, for example, the orbit gear 39 of

the differential, at 35. The shaft 85 is also operatively connected, through a speed-reducing train, at 85a, to the shaft 85b provided with an angularly movable arm 88 and operating limit switch mechanism, at 89, the limit switch mechanism including an "up" limit switch 90 and a "down" limit switch 92. With the opening of either limit switch a brake 100 is effective instantly to stop the motor, the brake being released by a solenoid 101 in circuit with the motor and engaged by a spring 102 upon breaking of the motor circuit.

The effect of loading in causing the elevator to lag more or less with respect to the pilot motor to secure the requisite extent of valve opening will be clear from diagrammatic Figs. 7 to 11, inclusive, and from a consideration of the fact that the valves, the pilot motor and the elevator are geared together through the differential. In Figs. 7 to 11, inclusive, the movement of the pilot motor is diagrammatically represented by an upper rack "a" engaging a gear "b", the elevator movement being represented by a lower rack "c" engaging the gear. Thus it will be seen that if rack "a" is given initial movement to the left (Fig. 7), the gear "b" will be translated toward the left, thereby opening the valve "d" connected to the gear. With opening of the valve "d" the elevator starts to move, the pilot motor being overspeeded at this time to secure quick elevator acceleration. With movement of the rack "c" to the right at the same speed as the rack "a" is moved to the left, transitory movement of the gear "b" will cease. With the elevator fully loaded and ascending, full power would be supplied to the cylinders, that is, the admission or supply valve 18 would be wide open for the elevator to travel with the pilot motor. On the other hand, in descending, the exhaust valve would be wide open for minimum load.

Fig. 7 shows diagrammatically the initial relation of the pilot motor and the elevator with the valve closed. Fig. 8 shows the relation of the elevator and the pilot motor with a valve wide open from which it will be evident that initial travel of the pilot motor has brought about acceleration of the elevator. The pilot motor and elevator travel together with the valve full open, and the wide open valve gives, through the differential, such a timing relation of elevator and pilot motor that, when the pilot motor opens either the "up" or the "down" limit switch (Fig. 9) the elevator will be at a point spaced sufficiently from the terminus being approached to provide for suitable elevator retardation due to closure of the valve by continued elevator motion. However, as shown in Fig. 11, when the valve is partially open due to load variation, lag of the elevator with respect to the pilot motor is less, the smaller the fractional opening of the valve the less the lag of the elevator with respect to the pilot motor, and, but for the provision of the elevator-operated potentiometer, at 41, the limit switch, "up" switch 90 or "down" switch 92, might be opened with the elevator too near to the terminus being approached for proper retardation. As the potentiometer is driven by the elevator and is therefore responsive to predetermined elevator travel, the effect thereof in bringing about pilot motor retardation depends upon the extent of elevator lag, the less the valve opening and the less the consequent elevator lag the more the potentiometer is relied upon to effect retardation. (See Fig. 11). Hence, due to the potentiometer and the limit switches, it is assured that, irrespective of loading and consequent extent of valve opening, the pilot motor will be retarded and/or stopped to bring about elevator

retardation a sufficient distance from a terminus being approached to avoid undue shock or impact.

Referring now to the potentiometer, at 41, and the elements of the control mechanism, shown more in detail in Fig. 3, L₁ and L₂ are the supply lines for the pilot motor 40 having an armature 105, the series field 106 and the shunt field 112. With the elevator in "down" position, the "down" limit switch 92 would have been opened and the "up" limit switch 90 would have been closed as the elevator reached down position (Fig. 2). Likewise, as the elevator reaches "up" position, the "up" switch 90 is opened and the "down" switch 92 is closed. In Fig. 3, the potentiometer setting is for the elevator in down position with the "up" limit switch 90 open.

The potentiometer includes a movable arm 107 connected to a shaft 108 driven by the elevator-driven shaft 38 so that the arm moves with the elevator, the arm being arranged to control resistances to vary the voltage impressed on the pilot motor, the resistance being controlled so that the pilot motor has maximum impressed voltage and runs at a speed above normal during the acceleration period, has normal impressed voltage and runs at normal speed during the main portion of the elevator flight, and is retarded, if either the limit switch 90 or the switch 92 is not opened when the elevator has travelled a predetermined distance. The less the lag of the elevator with respect to the pilot motor, the more effective is the potentiometer in effecting retardation. With maximum elevator lag, at which time the active valve is wide open, the limit switch is wholly effective to effect retardation; and, as the elevator lag is lessened incident to diminished valve opening, the potentiometer becomes more and more effective before the limit switch and the brake are operated until finally the potentiometer is fully effective to bring about reductions in impressed voltage the last tap corresponding to a minimum voltage providing a "creeping" motor speed. Under all conditions of operation, the pilot motor is stopped by its limit switch and brake, retardation of the elevator being dependent solely on stopping of the pilot motor when the active valve is wide open and being dependent upon retardation of motor speed, due to the potentiometer, followed by stopping of the motor and application of the brake at fractional openings, movement of the elevator after stopping of the motor being such that it would cause complete closure of the active valve if slight over travel of the elevator beyond the shaft abutments were permitted, whereby it is assured that an active valve shall not be completely closed when the elevator is stopped at a terminus but it is open sufficiently to provide pressure to maintain the elevator at a terminus. I show a variable potentiometer resistance element R having taps R₁ to R₁₄ connected to fixed segments U₁ to U₁₄ and D₁ to D₁₄. The segments or contacts U₁₄ to U₁ are engaged by a brush U₁₆ carried by one end of the arm 107 and electrically connected to a brush U₁₇ engaging the arcuate segment U₁₈. In like manner, the brushes D₁₆ and D₁₇ carried by the other end of the arm 107 establish connection of the contacts D₁₄—D₁ with arcuate segment D₁₈. Assuming that the elevator is in "down" position with the "up" limit switch 90 closed, then upon closure of the "up" push-button switch U₂₀, current would pass from line L₁ to the motor armature 105 to the tap R₁₄, segment U₁₄, brushes U₁₆ and U₁₇ and segment U₁₈, to provide for impressing over-voltage on the motor

to secure overspeed operation of the latter to accelerate the elevator in an "up" direction, the acceleration being completed about the time the brush U_{16} reaches the end of segment U_{14} . The brush passes to the main contact U_{12} connected to tap R_{12} to provide normal voltage impressed on the motor for normal speed of the latter for the main portion of the "up" flight. If the elevator is fully loaded, with the "up" valve 18 wide open, the elevator-moved brush U_{16} would reach the end of segmental contact U_{12} about the time the "up" limit switch 90 is opened, whereupon, as hereinbefore pointed out, the motion of the elevator acting through the differential moves the active valve in a closing direction to retard the elevator. The more the "up" load is decreased, the less the required opening of the "up" valve 18, and consequently the less the lag of the elevator and of the arm 107 relative to the pilot motor, and, but for the potentiometer, the limit switch 90 might open with the elevator too near to a terminus for proper retardation to be effected; however, this objection is avoided by the elevator-operated potentiometer. The potentiometer brush U_{16} engages successively the contacts U_{11} , U_{10} , et cetera, causing less and less voltage to be impressed on the motor to retard the speed of the latter, this action going on until the motor operates the limit switch. If the elevator lag is sufficiently small, the potentiometer may be fully effective to reduce the voltage impressed on the motor until the brush reaches "creeping" resistance contact U_1 connected to tap R_1 and the motor would have minimum impressed voltage and operate at "creeping" speed until stopped by opening of the limit switch.

With the "down" switch 92 closed and with the elevator in "up" position, to go down, the operator closes the "down" push-button type switch D_{20} and operation in the opposite direction of the pilot motor and elevator take place as described in connection with "up" operation, except that increase of elevator lag is caused by decrease instead of increase of loading.

Having referred to the potentiometer and to the limit switches somewhat in detail in securing retardation and stoppage of the pilot motor, the control devices and switches will now be referred to more particularly in other respects. Assuming that the elevator is in "down" position, then the "up" limit switch 90 would be closed, the closure of the limit switch 90 resulting in energization of the winding U_{22} to secure upward movement of the contactor U_{23} to bridge the contacts U_{24} . The operator depresses the push-button type contactor U_{20} to bridge the contacts U_{25} , thereby completing a circuit through the winding U_{26} of relay UR to energize the latter and raise the contactor U_{27} to bridge the contacts U_{28} , U_{29} , U_{30} , and U_{31} , connection of the contacts U_{28} providing for passage of current from the line L_1 to the tap R_{14} and to the segments U_{14} and D_{14} . With the contacts U_{24} already connected due to closure of the "up" limit switch 90, current, therefore, passes from the segment U_{14} through the brushes U_{16} and U_{17} , the arcuate segment U_{18} , the closed contacts U_{24} , the contacts U_{30} , the contacts 119g, to the brush 110, through the armature 105 to the brush 111, through the contacts U_{29} and the motor series field 106 to the other side L_2 of the supply line. Closure of the contacts U_{31} by upward movement of the contactor U_{27} results in completion of a shunt circuit through the winding U_{26} to maintain the latter energized so that the push-button type contactor

U_{20} may be immediately released after engagement. The circuit thus traced provides for operation of the motor in a direction suitable for "up" operation of the elevator. Upon closure of the contacts U_{24} , U_{28} , U_{29} , and U_{30} , the motor starts and operates in the manner heretofore described. Opening of the limit switch 90 is followed by stoppage of the motor due to application of the brake, whereupon continued motion of the elevator brings about retardation of the latter.

Down operation of the control mechanism is similar to the up operation just described. The operator depresses the push-button type contactor D_{20} to close the contacts D_{25} , the contacts D_{24} having already been closed due to energization of the winding D_{22} in consequence of closing of the down limit switches 92 and 93, closure of the contacts D_{25} resulting in energization of the winding D_{26} and upward movement of the contactor D_{27} of the relay DR to close contacts D_{28} , D_{29} , D_{30} , and D_{31} . Upon closure of the contacts D_{28} , current passes from the line L_1 to the tap R_{14} and to the segments U_{14} and D_{14} ; and, as the elevator-operated contact arm 107 would have stopped in "up" position with the brush D_{16} in engagement with the segment D_{14} , it will be apparent that current will pass from the segment D_{14} through the brushes D_{16} and D_{17} to the arcuate contactor D_{18} connected to one of the contacts D_{24} ; and, if the contacts D_{24} are closed, current will pass therethrough to the closed contacts D_{29} and from the latter to the brush 111 through the armature 105, and out through the brush 110 and through the closed contacts D_{30} to the series field 106 and to the other side of the line L_2 . Thus, it will be seen that the "up" and "down" relays UR and DR and the associated contacts provide for reverse rotation of the motor, current passing from the brush 110 through the armature 105 to the brush 111 for "up" operation of the elevator and from the brush 111 through the armature 105 to the brush 110 for "down" operation of the elevator.

If it is desired to stop the elevator while it is in flight, it is merely necessary to depress the contactor 114, opening of the contacts 115, and thereby opening the motor circuit in the same manner as the opening caused by opening of the second limit switches 91 or 93, the contacts 115 being in series with the second limit switches.

In order to provide for a desired overspeed of the pilot motor 40 during the acceleration period, I provide an adjustable resistance 117 arranged in series with the shunt field 112.

A safety switch 118 is associated with the push-button type switches U_{20} and D_{20} to prevent the operation of the latter from being effective unless the elevator is in "up" or "down" position. Also switches 119 and 120 are provided to stop the pilot motor in case the elevator does not start or does not accelerate fast enough. The switches 118, 119, and 120 are preferably operated by cam means 121 on the valve cam shaft 75. For example, I show a cam 121 having a depression 122 which permits closure of the switch 118 when the valve setting is for either "up" or "down" position of the elevator. The depression provides for opening of the switch 119 in case the pilot motor is started for "up" operation and the elevator does not follow fast enough, the shaft opening the valve 18 fully and overtravelling sufficiently to open the switch 119 and stop the motor. Opening of the switch 120 takes place in a similar manner for "down" operation. The switches, at 119 and 120, are each arranged to

provide for a two-phase control of the pilot motor, the first phase resulting in retardation of the motor and the second phase resulting in stoppage of the motor if the retardation is inadequate to provide for the elevator gaining on the motor. To this end, the switches, at 119 and at 120, include contacts 119a and 119b and 120a and 120b, the contacts 119a and 120a opening before the contacts 119b and 120b. The movable members of the switches, at 119 and at 120, are arranged in the circuits for the windings U_{2s} and D_{2s} , the contacts 119a and 120a being connected to a lead 119d containing the winding 119e and the stop switch 114. With opening of either the contacts 119a or 120a, the winding 119e is deenergized, the contactor 119f moves away from the contacts 119g of a branch of the armature circuit and the contactor 119w closes the contacts 119i of a second branch of the armature circuit containing the resistance 119k, the latter branch also including the contactor 119l which is held closed by the winding 119m as long as the latter is energized due to closure of the contacts 119b and 120b. Thus, it will be seen that, as soon as either contact 119a or 120a opens, due to partial entry of the curved end of the movable member of the switch, at 119 or at 120, the winding 119e is deenergized and the resistance 119k is placed in circuit with the armature, resulting in slowing down of the motor. If the elevator gains sufficiently, the cam will be moved to restore engagement of the disengaged contacts to cut out the resistance 119k and restore the motor to normal speed; however, if the motor continues to gain relatively to the elevator, the movable switch member will bottom in the recess 122 and open the contact 119b or 120b, whereupon the winding 119m will be deenergized and the motor circuit will be interrupted to stop the motor.

In Fig. 15, I show a second embodiment of my invention wherein the motor is provided with means for effecting its acceleration and retardation in response to elevator travel, motion derived from the elevator and utilized to effect motor acceleration and retardation being also utilized through the instrumentality of the second differential, at 145, to open or to close a valve, the valves being under the control of the elevator and of the pilot motor, acting through the first differential, at 137, so that the elevator follows the motor. In this view, the elevator 125 is raised and lowered, as before, by liquid medium admitted to and exhausted from the hydraulic cylinder 126 through the conduit 127, the conduit communicating with the pressure valve 128 and the exhaust valve 129, the valve 128 being supplied with liquid under pressure from the high pressure tank or reservoir 130 and liquid being exhausted, when the valve 129 is open, to the low pressure tank 131.

To simplify the illustration, the valves 128 and 129 are shown as being opened and closed by oscillatory mechanism, at 132, actuated by the nut 133 engaging the screw 134 carried by the actuating or output shaft 135. If the shaft 135 is rotated in one direction, the valve 128 is opened and liquid under pressure is admitted to the cylinder 126 to raise the elevator; on the other hand, if the shaft 135 is rotated in the other direction, the valve 128 is closed and the valve 129 is opened to allow liquid to exhaust from the cylinder 126 in order to lower the elevator.

Referring now to the means for rotating the output or operating shaft 135 in one direction or the other, this is accomplished by the cooperative

effect of motion of the elevator and a pilot motor. To this end, I show a differential, at 137, having one input element, for example, the sun gear 138 carried by the shaft 139, the latter shaft being connected to the elevator through suitable transmission mechanism indicated at 140. The second motion input element of the differential, for example, the orbit gear 141, is connected by worm gearing 142 to the pilot motor, at 143. The output element of the differential, at 137, for example, the planet pinions 144, instead of being connected to mechanism for operating the valves, as in the embodiment previously described, is connected to a second differential, at 145, and serves as a motion input element of the latter.

The pilot motor, at 143, is arranged to have a travel corresponding to the elevator. The elevator is started by first starting the pilot motor, its relative motion to the elevator securing opening of the proper valve and causing the elevator to start and accelerate to follow the pilot motor. Near the end of a trip, the pilot motor is retarded to bring about retardation of the elevator and finally the pilot motor is brought to a stop.

In Fig. 15, the pilot motor is shown as being of the shunt type in which variation in speed of the motor is effected by variation in field resistance and in which reversal is secured by reversing the field circuit. It is to be understood, however, that the means shown for obtaining speed variation and reversal is presented by way of example and may be modified as long as the essential principles of operation are preserved.

The elevator-driven shaft 139 has a screw 150 with a nut 151 thereon. If the elevator ascends, the nut moves in one direction; and, if it descends, the nut moves in the other direction. Motion of the nut is used to secure variation of armature resistance as well as interruption and establishment of proper circuit relations.

Referring now to the control for the circuits of the motor, at 140, it will be noted that "up" and "down" switches are provided, at 152, and, at 153, respectively, and a reversing switch, at 154, is provided having a movable contactor 155. The field circuit of the motor is provided with a resistance 156 with which cooperates the movable contactor 157.

The movable contactors 155 and 157 are actuated by the nut 151. To this end, I show the contactor 155 carried by snap-over supports 158 having a spring 160 associated therewith to give such action to the contactor 155 as soon as the latter passes mid-position. Assuming that, in descending, the nut 151 has travelled to the left, near the end of its travel, the left-hand support 158 will be engaged to move the contactor 155 from its extreme right-hand position and when the supports pass beyond dead-center position the spring 160 will snap the contactor quickly over to the extreme left-hand position. Assuming that the elevator is ascending, the nut will travel to the right; and, at the end of its travel, it will snap the contactor from its extreme left-hand position to the extreme right-hand position. The nut 151 also cooperates with abutment elements or levers 161 for moving the contactor 157. As shown, the levers 161 are fulcrumed at 162 and are pivotally connected at 163 to the outer ends of links 164, the inner ends of the links being pivotally connected at 165 to the contactor 157. A spring 166 tends to move the contactor 157 in a counter-clockwise direction. Thus, it will be seen that, upon outward movement of either lever 161, the contactor 157 will

be moved in a clockwise direction to decrease the resistance in the field circuit, in order to decrease the motor speed.

Referring now more particularly to the reversing switch 154, as shown in Fig. 15, when the elevator is in "down" position, the contactor 155 is at the extreme right bridging the contacts 170 to connect the conductor 171 to the conductor 172 connected to the contactor 157 and the contacts 173 will be bridged to connect the field 174 to the side L_2 of the supply line. Also movement of the nut 151 to bring the contactor 155 to this position will have also actuated the contactor 157 to cut out the resistance 156. If the "up" switch, at 152, is now closed, the circuit will be completed from the side L_1 of the line through the contacts 170, the contactor 157, the field 174, and the contacts 173 to the side L_2 of the line. Also, with energization of the field circuit the armature circuit will be completed through the magnetic contactor 175. The elevator now travels in an upward direction, the resistance being inserted due to movement of the contactor 157 by the spring 166, as the nut 151 recedes from its left-hand position, thereby bringing about acceleration of the motor to normal speed. As the elevator approaches its top position, the nut contacts with the right hand supporting lever 158 and with the right-hand lever 161, the contactor 155 and its supporting levers 158 being thereby moved toward the left, and, as soon as dead center position is passed, the spring 160 causes snap-over action of the contactor 155 to its extreme left-hand position, this movement bringing about interruption of the "up" motor circuit and preparing the "down" circuit for completion by closure of the "down" push button, at 153.

In its extreme left-hand position, the contactor 155 bridges the contacts 176 and 177 to establish a circuit in the reverse direction through the field 174, this reverse circuit being subsequently completed by closure of the push button, at 153.

The differentials, at 137 and 145, provide for the elevator following the pilot motor closely, the first differential, at 137, assuring that the elevator shall be under control of the pilot motor and the second differential, at 145, assuring closer following of the pilot motor by the elevator during acceleration and retardation periods. The output shaft 178 of the differential, at 137, is connected to one of the motion input elements, for example, the planet pinions 179, of the second differential, at 145. The second motion input element of the differential, at 145, for example the orbit gear 180, is provided with a pinion 181 meshing with a gear 182 connected by the bevelled gears 183 and 184 to the oscillatory contactor 157. With this arrangement of apparatus, it will be evident that motion used to secure operation of the rheostat 156, or its equivalent, to accelerate or to retard the motor is also utilized for the purpose of opening or closing an active valve, the differential, at 137, serving primarily for the purpose of causing the elevator to follow the pilot motor.

The pressure and exhaust valves suitable for the apparatus so far described are preferably of the type shown in detail in Fig. 12. Since the valves 18 and 19 are structurally similar, a description of one will be sufficient. The valve 18 is comprised by a housing 186 having chambers 187 and 188 separated by a seat 189 with which cooperates the cylindrical valve body 190 guided by the cylindrical guide 191 depending into the chamber 187, the valve body fitting the guide with

a close fit and preferably being provided with ring packing to reduce leakage, particularly when the valve is seated. The valve body has a pressure balancing passage 192 to facilitate opening and closing movement thereof.

Instead of having the valve body 190 rigidly connected to the stem structure 82 actuated by the cam 76, features of construction are provided assuring seating of the valve body irrespective of small relative displacement of parts such as due to temperature changes, to manufacturing tolerances, to slight deviations from ideal adjustment, and to the cam operation hereinafter pointed out. To this end, the stem construction includes a head 192 having its upper end provided with the cam roller 80 and having its lower portion formed as a ram fitting the guide 193 and having a threaded bore 194. An externally threaded thimble 195 engages the bore threads and the upper end thereof clamps the collar 196 with respect to the bottom of the bore, the collar being connected to a sleeve 197 threaded to the upper end of the stem 198 and held in adjusted position by the jam nut 199. Thus it will be seen that a fine degree of length adjustment of the stem construction may be had to secure proper operation of the valve body.

The stem 198 extends downwardly through the gland or stuffing box 198a and into the guide chamber 191, the lower portion of the stem being disposed within the bore 200 provided in the valve body. The stem has a collar 201 adjacent to the top of the valve body, the upper face of the collar abutting a detachable cover 202 carried by the valve body. The lower face of the collar is engaged by a thimble abutment 203 fitting the bore 200 and the stem 198 and pressed upwardly by the spring 204 disposed in the bore. The spring connection between the stem construction and the valve body permits of sufficient overtravel of the stem with respect to the valve body to assure of the latter seating; and, as above pointed out, this feature assures of proper operation in service even though there may be minor relative displacements of parts. Furthermore, the spring connection provides for mechanical seating of the valves under a desired pressure, the lengths of the stem constructions being suitably adjusted.

The cams 76 and 77 are similar except that the grooves 78 and 79 are reversely arranged to secure reciprocal operation of the valves and they are angularly displaced sufficiently to assure that either valve is held closed under spring pressure before the other valve is opened, this result being assured, as hereinbefore pointed out, by having the stem construction overtravel the valve in a closing direction, the excess travel being taken up by compression of the spring 204. Upon reference to diagrammatic Fig. 14, it will be seen that, not only is one cam the direct opposite of the other, but that the cams are displaced angularly relatively to each other. By way of example, I show each cam having a portion from a to c which is of constant radius and a portion from a to b of diminishing radius. When the point d , whose radius od is less than the radius oa , of either cam, acts on the valve follower the spring compression is relieved and the valve would be just seated, that is, motion from d in a radius-decreasing direction results in opening of the valve and motion from d in a radius-increasing direction results in increased compression of the valve spring holding the valve closed. When the elevator reaches a terminus, it being stopped by the shaft abutments or stops, the active valve would have been mov-

ing in a closing direction due to the increasing radius of the cam acting thereon; however, the elevator would be stopped with a cam radius slightly less than the radius *od*, thereby assuring that the active valve would not quite close in order to provide pressure to hold the elevator against the stops or abutments. It will also be apparent that, if the active valve is not completely closed by its associated cam, the other cam will be in such position as to maintain compression of the spring of the other valve, it being possible to relieve compression of both valves only when the radii *od* of the cams act on the two valves at the same time. Any tendency of the elevator to creep in either direction causes the cams to operate the valves to resist such a tendency. If the elevator is stopped in midflight by both valves being brought to neutral position by the elevator, that is, with the radii *od* of the cams effective to adjust and hold the valves seated without any spring compression any tendency of the elevator to creep in either direction is resisted by consequent disturbance of the neutral relation of the valves, that is, if the elevator should attempt to creep in either direction, the valve for controlling fluid for movement of the elevator in the other direction would be opened slightly, with the result that the elevator would be brought to a stationary position at which time the valves would occupy such relative relations as to maintain an equilibrium condition, either valve opening just sufficiently to compensate for leakage so as to provide for maintenance of a pressure holding the elevator stationary.

The foregoing valve operation will now be considered in relation to the elevator. As heretofore pointed out, the elevator is started, by starting the pilot motor, the motion of the latter relative to the elevator operating through the differential to open one of the valves, whereupon the elevator starts and is accelerated, and, due to motion of the elevator relatively to the pilot motor tending to close the valve, the flight speed will be controlled by the pilot motor, the degree of opening of the valve depending on the load. It has also been pointed out that the pilot motor is retarded as the end of a trip is approached, this retardation being accompanied by the motion of the elevator operating through the differential to move the valve in a closing direction to slow down the elevator, the elevator thereby tending to attain a speed corresponding to the pilot motor.

As retardation of the elevator follows that of the pilot motor, further travel of the elevator is necessary after the pilot motor comes to a stop before the elevator can stop its operation through the differential. For example, assuming that the elevator is to be stopped in mid-flight, the appropriate push button is operated to open a circuit to stop the pilot motor, but the elevator continues to travel and may travel, for example, a distance of three feet, before it can restrict the active valve sufficiently to bring the elevator to a stop. It is, therefore, necessary to provide for retardation of the elevator before the end of a trip so that the elevator itself may act through the differential to bring about its own retardation, and this entails suitable advance retardation of the pilot motor. As heretofore pointed out, depending upon the loading and consequent extent of valve opening, this determining the extent of lag of the elevator with respect to the pilot motor, the pilot motor is retarded either by a switch operated after predetermined travel of the pilot motor or by a potentiometer operated after predetermined elevator travel followed by operation of the limit

switch, the limit switches assuring stoppage of the pilot motor so that the necessary travel of the elevator to completely close the active valve shall be slightly in excess of the actual travel limited by the elevator shaft stops, whereby it is assured that, when the elevator is stopped by the abutments, the active valve is not quite closed so as to maintain pressure adequate to hold the elevator at the terminus.

In Fig. 16, I show a further application of my invention for moving a body, for example, a steering arm 205, the arm being connected to a piston rod 206 having a piston 207 at one end arranged in the double acting cylinder 208. High-pressure and low-pressure storage chambers 209 and 210 are provided as before, but the valve arrangement is different on account of double-acting operation.

I show the cylinder 208 provided with inlet and exhaust passages 211 and 212 at the ends thereof, said passages terminating in spaced ports 213 and 214 communicating with the piston valve cylinder 215. The high-pressure chamber 209 has a passage 216 terminating in a port 217 communicating with the cylinder 215 and preferably disposed midway between the ports 213 and 214. The piston valve cylinder 215 also has ports 218 and 219 disposed outwardly from the ports 213 and 214, respectively, and communicating with a passage 220 leading to the low pressure chamber 210.

A piston valve 221 is arranged in the cylinder, the piston valve having piston portions 222 and 223 so spaced that when the valve is in neutral or middle position the piston portions lap the ports 213 and 214. If the piston valve is moved toward the right, the port 217 will be placed in communication with the port 214 and fluid will be supplied from the high-pressure chamber 209 to the right-hand end of the cylinder 208, fluid being exhausted from the left-hand end of the cylinder through the communicating ports 213 and 218 to the low-pressure chamber 210.

The piston valve 221 is provided with a stem 225 to be actuated by means hereinafter described. While I have shown a piston valve arrangement for securing double acting-operation of the piston 207, it is to be understood that this showing is merely illustrative and that other arrangements for the same purpose may be used.

The stem 225 of the piston valve is preferably actuated by a cam 226 connected to the output shaft 227 of the differential, at 228, the shaft 227 being connected to the output gear, for example, the sun gear 229, of the differential. The differential has two motion in-put elements for example, the planet pinions 230 and the orbit gear 231. The planet pinions 230 are connected, by suitable gearing, to the piston rod 206 so that motion of the latter is fed back to the differential, and the input gear 231 may be moved in any suitable manner, for example, by the motor 232 geared thereto, the motor having its motion controlled in any suitable manner.

By way of example, I show the motor 232 provided with a controller, at 233, of the follow-up type, the controller including a commutator element 234 having contact segments 235 and 236 and a movable contactor 237 is disposed for co-operation with either contact segment 235 or 236, the movable contact 237 being shown in neutral position between the segments and being carried by a controller lever or handle 238. Upon movement of the handle 238 to engage the contact 237 with the segment 236, the motor 232

runs in one direction; and, upon engagement of the contact with the other segment 235, the motor runs in the other direction, whereby the piston 207 is caused to move in one direction or the other to secure desired movement of the arm 205.

The extent of motion of the motor 232 is dependent upon the extent to which the controller handle 238 is moved and the follow-up motion given to the commutator by the motor, the motor being connected to the commutator by any suitable means, for example, by a gear train, at 240. If, for example, the lever 238 is moved clockwise from the neutral position a predetermined distance then the motor 232 will travel a distance proportional to the lever displacement, for, operation of the motor results in movement of the commutator 234 in the same direction as the lever was moved until the commutator is brought to neutral position. Thus, it will be seen that, by moving the lever 238 in either one direction or the other, the motive piston 207 may be caused to move correspondingly.

The term "retardation", as used herein with respect to the pilot motor, covers either the operation where the limit switch is opened and the brake is applied or the operation where the potentiometer is first effective to bring about pilot motor speed reduction followed by stopping of the pilot motor incident to opening a limit switch and applying the brake.

While I have shown my invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:—

1. The combination with a body normally movable in opposite directions, of means for moving the body in opposite directions including means for controlling the application of energy thereto, a differential having a motion output element connected to said controlling means and having a pair of motion input elements, means for transmitting motion from the body to one of said input elements, and means for providing and applying controlled motion in either direction to the other of said input elements.

2. The combination with a body normally movable in opposite directions, of hydraulic motor means for moving the body in opposite directions including valve means for controlling the application of motive liquid thereto, a differential having a motion output element connected to the valve means, and having a pair of motion input elements, means for transmitting motion from the body to one of said input elements, and means for applying controlled motion in one direction or the other to the other of said input elements.

3. The combination with an elevator, of means for raising and lowering the elevator including means for controlling the application of energy thereto, a differential having a motion output element connected to said controlling means and having a pair of motion input elements, means for transmitting motion from the elevator to one of said input elements, and reversible motor means connected to the other of said input elements.

4. The combination as claimed in claim 3 with means for starting the motor before the elevator starts in order that motion of the motor relative

to the elevator may be utilized by the differential to operate the controlling means to start and accelerate the elevator and with means for retarding the motor as the end of an elevator trip is approached in order that motion of the elevator relative to the motor may be utilized by the differential to operate the controlling means to effect retardation of the elevator.

5. The combination with an elevator, of means for raising and lowering the elevator including means for controlling the application of energy thereto, a differential having a motion output element connected to the controlling means and having a pair of motion input elements, means for transmitting motion from the elevator to one of the input elements, a reversible electric motor connected to the other of said input elements and means for controlling the motor so that the latter has a predetermined travel in each direction.

6. The combination with an elevator, of means for raising and lowering the elevator including means for controlling the application of energy thereto, a differential having a motion output element connected to the controlling means and having a pair of motion input elements, means for transmitting motion from the elevator to one of the input elements, a reversible electric motor connected to the other of said input elements, means providing for starting of the electric motor in either direction, and means providing for retardation of the motor as the end of each elevator trip is approached.

7. The combination as claimed in claim 6 wherein retardation of the motor is effected by means operated thereby after predetermined travel.

8. The combination as claimed in claim 6 wherein retardation of the motor is effected by means operated by the elevator after predetermined travel of the latter.

9. The combination as claimed in claim 6 wherein the motor retardation means is effective in response both to predetermined motor travel and to predetermined elevator travel.

10. The combination with an elevator, of means for raising and lowering the elevator including means for controlling the application of energy thereto, a differential having a motion output element connected to the controlling means and having a pair of motion input elements, means for transmitting motion from the elevator to one of the input elements, a reversible electric motor connected to the other of said input elements, means providing for variation in speed of the motor, and a controller operated by the elevator for securing adjustment of the speed-varying means to operate the motor at an overspeed during the initial portion of its travel to start and accelerate the elevator and then to operate the motor at normal speed for the main flight travel of the elevator.

11. The combination as claimed in claim 10 with means for stopping the motor before the end of each trip.

12. The combination with an elevator, of hydraulic means for raising and lowering the elevator including pressure and exhaust valves, means for securing alternative valve operation including a rotary member, a differential having a motion output element connected to said rotary member and having a pair of motion input elements, means for transmitting motion from the elevator to one of said motion input elements, a reversible motor connected to the other of said input elements, upper and lower abutments for stopping the elevator at the limits of its travel, and con-

trolling means for the motor providing for retardation of the latter to effect retardation of the elevator before motion of the latter is stopped by either abutment.

13. The combination as claimed in claim 12 wherein the controlling means for the motor also provides for overspeed operation of the latter for an interval after starting sufficient for starting and acceleration of the elevator and provides for travel of the motor corresponding to an elevator travel slightly in excess of the real elevator travel.

14. The combination with an elevator, of hydraulic means for raising and lowering the elevator including pressure and exhaust valves, a member for operating said valves alternatively, a differential having a motion output element connected to said member and having a pair of motion input elements, means for transmitting motion from the elevator to one of said input elements, and a reversible pilot motor connected to the other of said input elements.

15. The combination as claimed in claim 14 with controlling means for the pilot motor providing for starting of the latter to start and accelerate the elevator and providing for its retardation as the end of each elevator trip is approached in order to retard the elevator.

16. The combination as claimed in claim 14 with controlling means providing for starting and overspeed operation of the motor to quickly accelerate the elevator, then providing for normal speed of the motor to secure normal flight speed of the elevator, and providing for retardation and stoppage of the motor as the elevator approaches the end of each trip to effect retardation of the elevator.

17. The combination with an elevator, of hydraulic means for raising and lowering the elevator including pressure and exhaust valves, a member for operating said valves alternatively, a differential having a motion output element connected to said member and having a pair of motion input elements, means for transmitting motion from the elevator to one of said input elements, a reversible electric pilot motor connected to the other of said elements, a pair of manual switches for securing operation of the motor in both directions, motor retarding means, limit switches operated by the motor near the end of each trip to stop the motor to bring about elevator retardation, and a potentiometer operated by the elevator and responsive to predetermined elevator travel to retard the motor unless the latter has been stopped by opening of a limit switch.

18. The combination with an elevator, of hydraulic means for raising and lowering the elevator and including first and second pressure and exhaust valves; control mechanism for the first valves including a rotary member, a differential having its output element connected to the rotary member and having a pair of motion input elements, a reversible electric motor connected to one of said input elements, means for transmitting motion from the elevator to the other of said input elements and including a clutch whose

members have a single relative position for engagement; circuit means for the motor including a switch; manually operable means for controlling said second valves; manual means for disengaging said clutch and opening said switch; and an interlock between the last two means to prevent operation of the first without the second having been operated to disengage the clutch and open the motor switch.

19. The combination with an elevator, of hydraulic means for raising and lowering the elevator and including first and second pressure and exhaust valves; control mechanism for the first valves including a rotary member, a differential having its output element connected to the rotary member and having a pair of motion input elements, a reversible electric motor connected to one of said input elements, means for transmitting motion from the elevator to the other of said input elements and including a clutch whose members have a single relative position for engagement; circuit means for the motor including a switch; and means providing for manual actuation of said second valves only after said clutch is disconnected and the motor switch is opened.

20. In an elevator, hydraulic means for raising and lowering the elevator and including pressure and exhaust valves having movable valve bodies; mechanism for operating said valves including a pair of angularly displaced cams carried by a rotary member, stem constructions having followers engaging the cams, and yieldable means interposed between the stem constructions and the valve bodies and providing for overtravel of the stem constructions in a valve seating direction with seating of the valves under pressure; a differential having a motion output element connected to said rotary member and having a pair of motion input elements; means for transmitting elevator motion to one of said input elements; and a reversible pilot motor connected to the other of said input elements.

21. The combination as claimed in claim 20 with means providing for length adjustment of the stem constructions.

22. In an elevator, hydraulic means for raising and lowering the elevator and including pressure and exhaust valves, stems for the valves, springs arranged between the stems and the valves and providing for overtravel of the stems in valve closing direction to hold the valves closed under pressure, a pair of connected cams for actuating said stems, the cams being similar but reversely arranged and being relatively angularly displaced so that either valve is closed and has spring pressure exerted thereon before the other valve starts to open, a differential having an output element connected to the cams for operating the latter and having a pair of input elements, means for transmitting elevator motion to one of said input elements, and a reversible pilot motor for the other input element.

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